High resolution magnetic imaging of perpendicular magnetic recording media by near-surface alternating magnetic force microscopy with amorphous FeCoSiB tip

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There is a need to develop ultra high resolution imaging techniques to completely understand the nanomagnetic behaviour of systems and support in the development of high density recording media and head technologies to fulfil the future requirements. Magnetic force microscopy (MFM) is a useful tool to investigate the surface magnetic domain structures in detail. Unfortunately, it is difficult for conventional MFM to detect magnetic force near the sample surface where short range forces are dominant. In order to improve ultra high spatial resolution, we developed alternating magnetic force microscopy (A-MFM) technique which enables to image DC & AC magnetic fields gradients near the sample surface in ambient atmospheric conditions with high spatial resolution [1-2]. A-MFM technique utilizes the frequency modulation (FM) of a cantilever oscillation generated by an off-resonance alternating magnetic force between a magnetic sample and a magnetic tip. For DC magnetic field imaging, A-MFM uses a soft magnetic tip of which magnetic moment is driven by an AC magnetic field to generate the alternating magnetic force. A-MFM can distinguish the zero level and the polarity of magnetic force and also carry out direction-detectable static magnetic fields imaging. By using these merits, we can detect the amplitude and direction of perpendicular DC magnetic fields from the sample surface simultaneously. The spatial resolution less than 10nm was obtained by soft magnetic FeCo crystalline tips. Here the resolution was determined by the half of the minimum wave length where MFM magnetic signal reaches white noise level for the A-MFM image. To obtain ultra high spatial resolution, development of a sharpened soft magnetic tip with high sensitivity is quite important.

In the present study, soft magnetic FeCoBSi amorphous tips were developed with high magnetization by directional sputtering deposition method which makes the tip apex sharp corner and also optimized the FeCoBSi film thickness, measuring conditions for high resolution A-MFM imaging. Fig. 1(a) shows the schematic diagram of A-MFM for DC magnetic field measurement. Ultra high-spatial resolution less than 5nm (Fig.1(d)) was obtained for the spatial spectrum of A-MFM line profile (Fig.1 (c)) of A-MFM image (Fig. 1(b)) of CoCrPt-SiO_2 perpendicular magnetic recording media with a recording density of 500kfci. The key reasons for ultra high resolution are film coating technique, high magnetization and amorphous nature makes smooth surface and also near surface imaging. By taking the advantages, A-MFM with the high-sensitivity soft magnetic tipis thought to be quite effective to observe high-density recording media, granular films and ferromagnetic nanoparticles

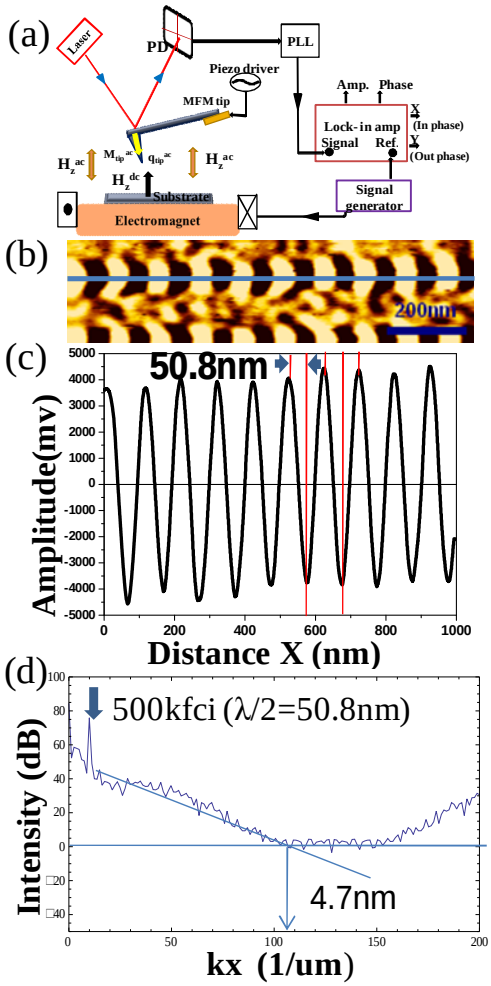

Figure 1 (a) Schematic diagram of alternating magnetic force microscopy for DC magnetic field measurement, (b) A-MFM image of lock-in detected in-phase signal corresponding line profile (C) and spatial spectrum (d) respectively.

REFERENCES

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2) H. Saito et al., *J. Appl. Phys.*, 109, 07E330, (2011).

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